

An Overview of ALD Equipment for Semiconductor Applications

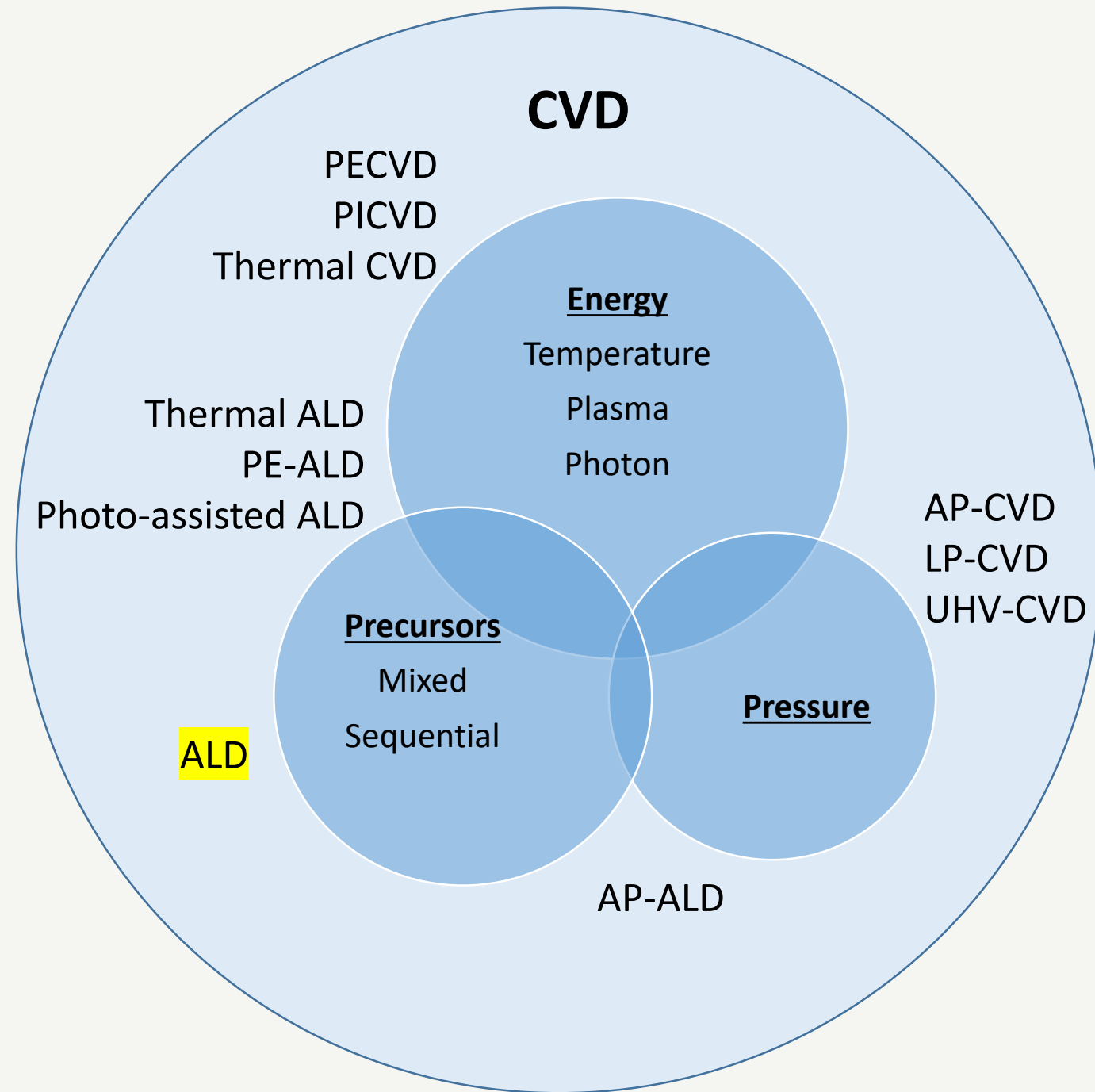
Two horizontal lines, one blue and one yellow, extending from the left and right edges of the slide towards the center.

J. Nie
05/2021

Note: All data, images, and pictures have open access. All sources are documented for easy reference by readers

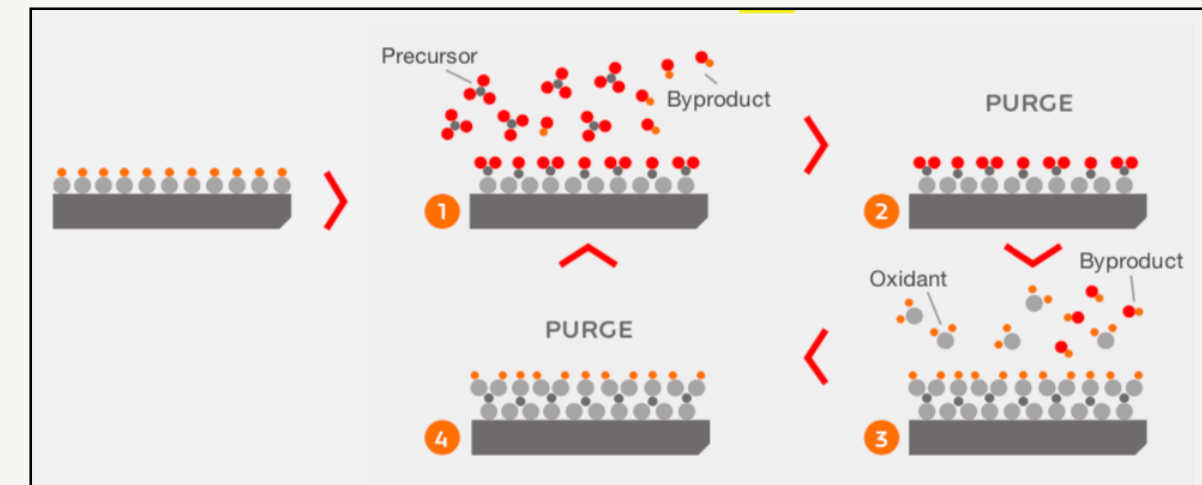
What is ALD?

- Categories



- ALD Mechanism

- dividing CVD to two half-reactions



ASM 2020 Annual Report

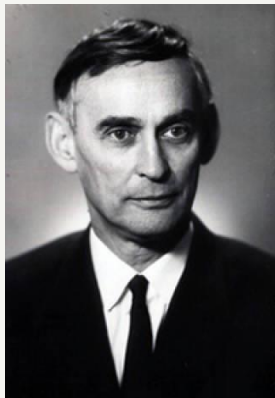
- ALD Applications

- Microelectronics
- Display
- Medical

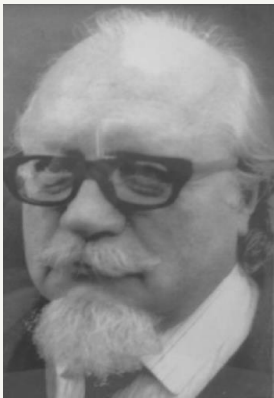
A Brief History: From Academia to Industry



Valentin Aleskovsky, USSR
Physical Chemist (1912-2006)
1952 Hypothesis,
[doi:10.1002/cvde.201502013](https://doi.org/10.1002/cvde.201502013)



With Stanislav Koltsov (1931-2003)
Experiments at LTI, USSR
1965, Molecular Layering Technique



Built the foundation of Modern ALD	
Year	Reaction
1970	TiO2/Si
1970	SiO2/Si
1978	High-k HfO2 & ZrO2
1979	MOS Diodes Cr2O5, V2O5/Si
1985	SiN
1985	Carbon

Aarik, J, et al. VPHA, 2014

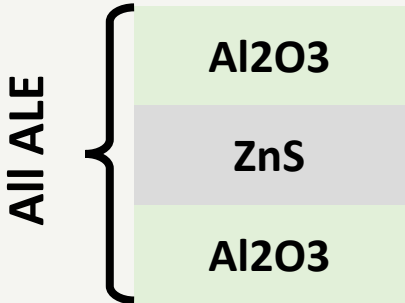
Two
independent
origins for
two paths



Tuomo Suntola, Finland
Physicist (1943-)



At Instrumentarium, Finland
1974, ZnS, Atomic Layer Epitaxy
[doi: 10.1016/S0920-2307\(89\)80006-4](https://doi.org/10.1016/S0920-2307(89)80006-4)

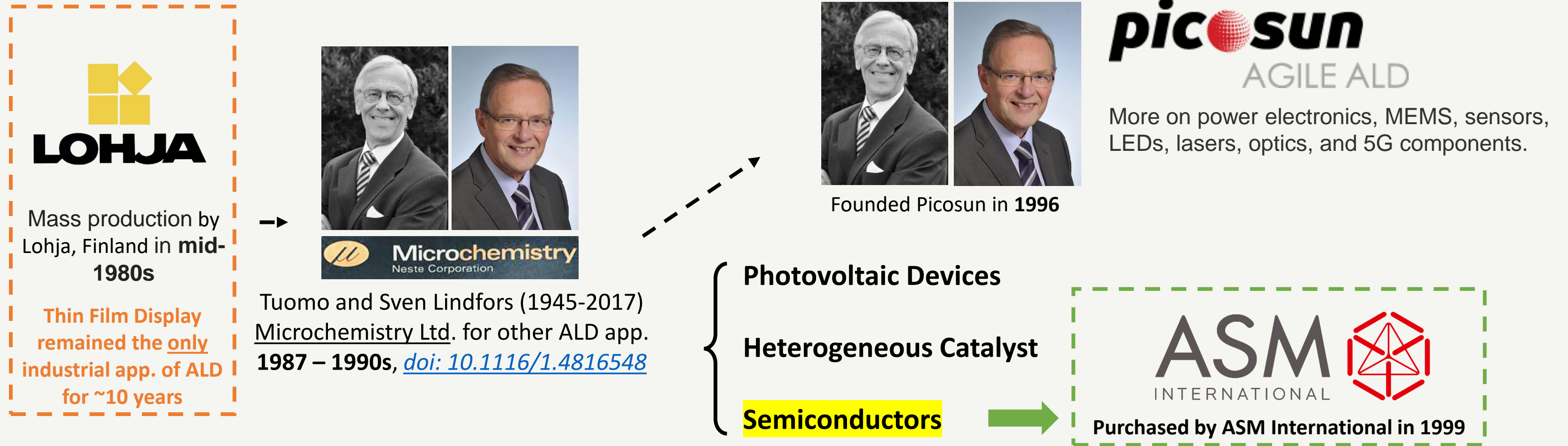


World's first ALE Stack
thin-film electroluminescent
displays in **1980**

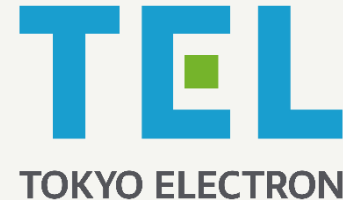


Mass production by Lohja,
Finland in **mid-1980s**

A Brief History: From Academia to Industry



In 2000s, a lot more players joined the game. For example,

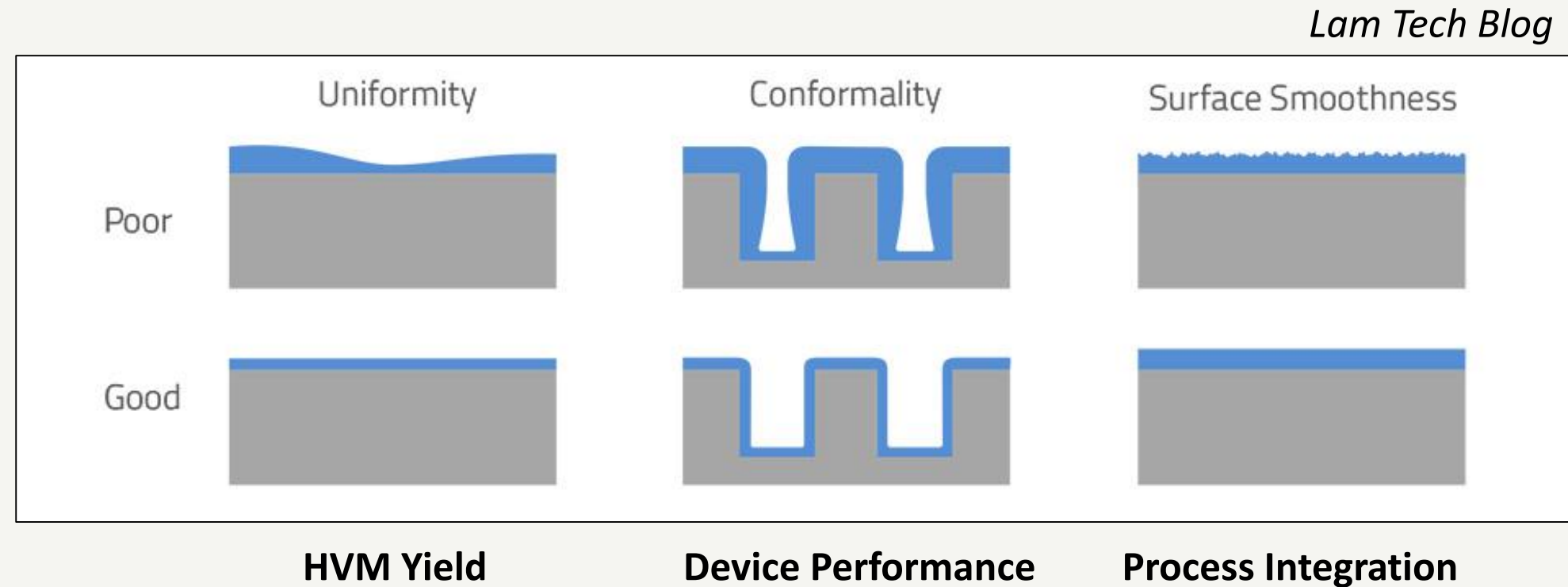


est. 2015

Why or Why not use ALD?

- **ALD Advantages**

- Good uniformity and conformality

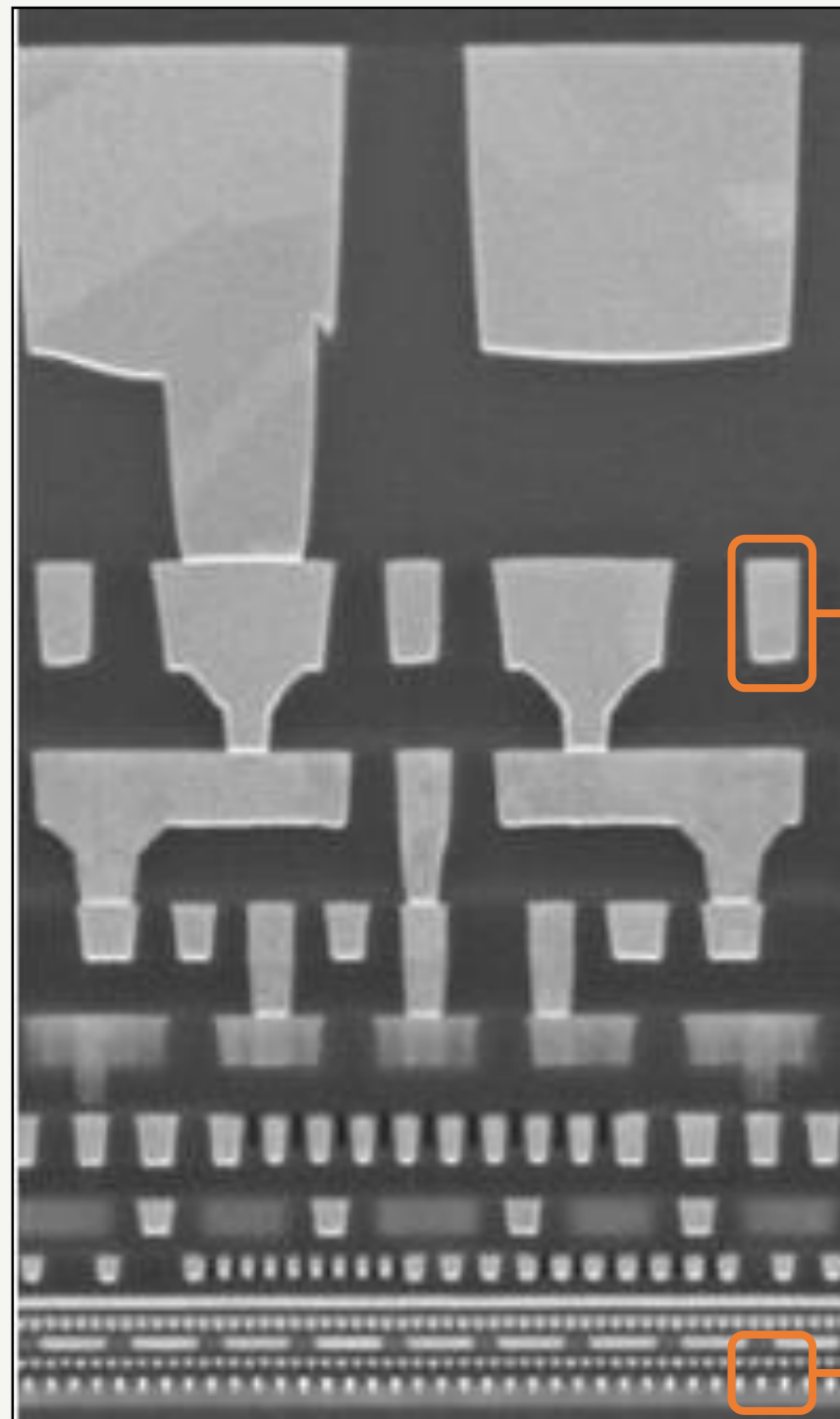


- Low defects
 - Low damage to substrate

- **ALD disadvantage**

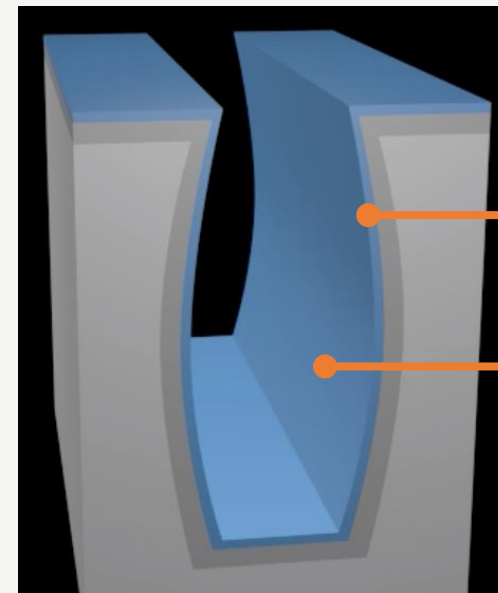
- Low throughput
 - Require high purity (substrate, chemicals)
 - High equipment upfront cost
 - Chemicals needs to be volatile (a disadvantage vs. PVD)

Logic Applications



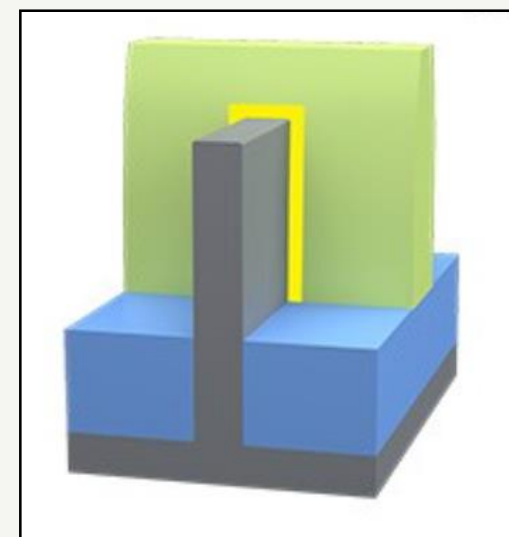
Fischer K. 2016, IEEE

NOW



AMAT Tech Blog

- Metal Barriers
- Metal Seed layer

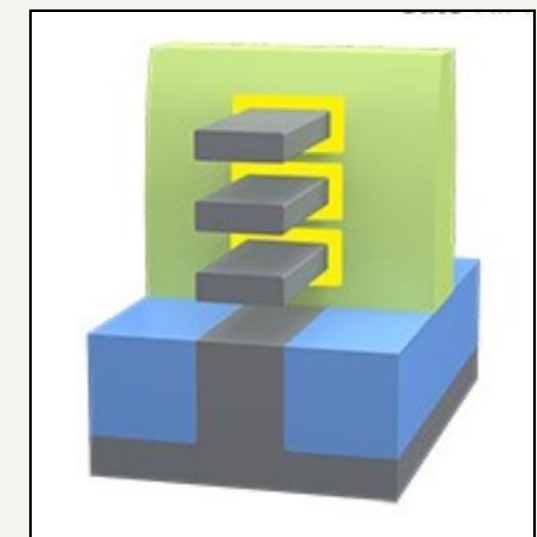


Lam Tech Blog

- High-k
- metal gate

FUTURE

- **MORE LAYERS**



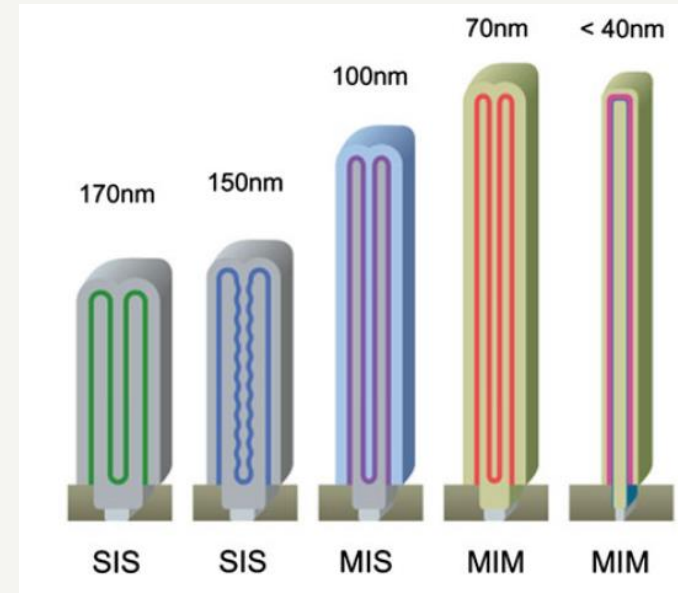
Lam Tech Blog

Memory Applications

■ ALD for DRAM

- Dielectric and Electrode for Capacitors (High Aspect Ratio, Controlled electric performance)
- Sacrificial Layers

NOW



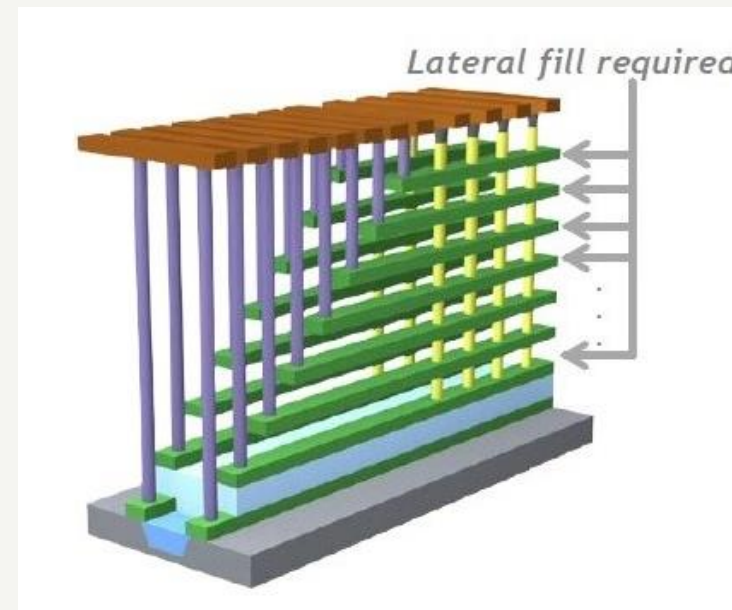
Hwang CS, 2014

FUTURE

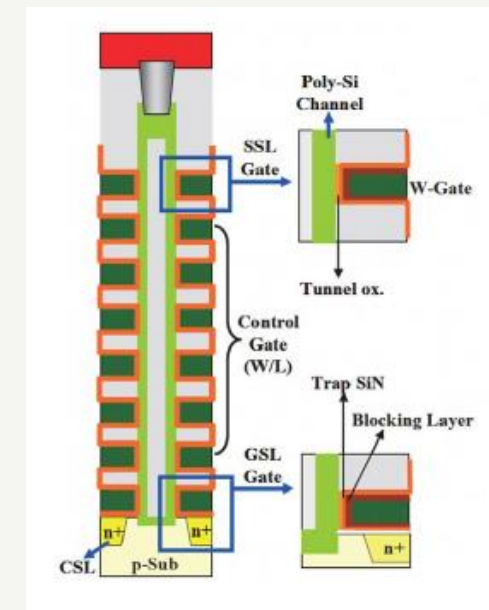
- Higher aspect ratio
- Maintaining electrical performance
- Lower tool cost

■ NAND

- High Aspect Ratio + Lateral Filling
 - W Metal
 - Trap Layer
 - Blocking Layer



Lam Tech Blog



Kessels E, 2019

HVM Leader - ASMI

- **Prompt decision making on disruptive tech** *Jorijn van Duijn, Futures of High Tech, 2019*
 - In 1999 Jan, ASM C-level confirmed interest within 1 week after initial meeting
 - In 1999 July, ASM finalized the acquisition.



Technology (w ~40ish employees)



global infrastructure, Customer resources, Engineering team

Product	Pulsar	EmerALD	Synergis (2018)
Application	High-k dielectric	Metal gate electrode	Metal, Metal oxide, Metal nitride
Platform	XP		XP8

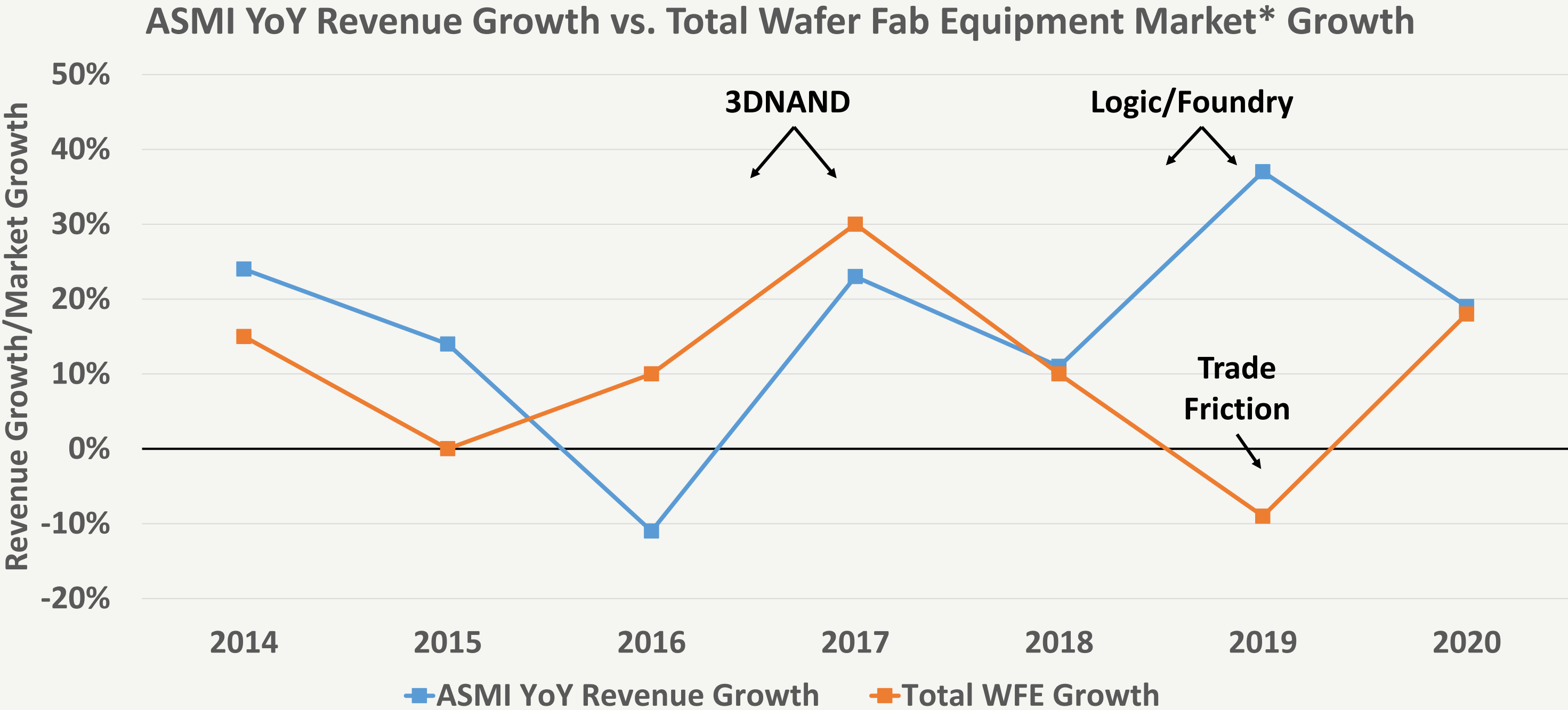


4-Module Platform
Parallel processing / Sequential steps



8-Module Platform
Upgrade of XP with higher productivity

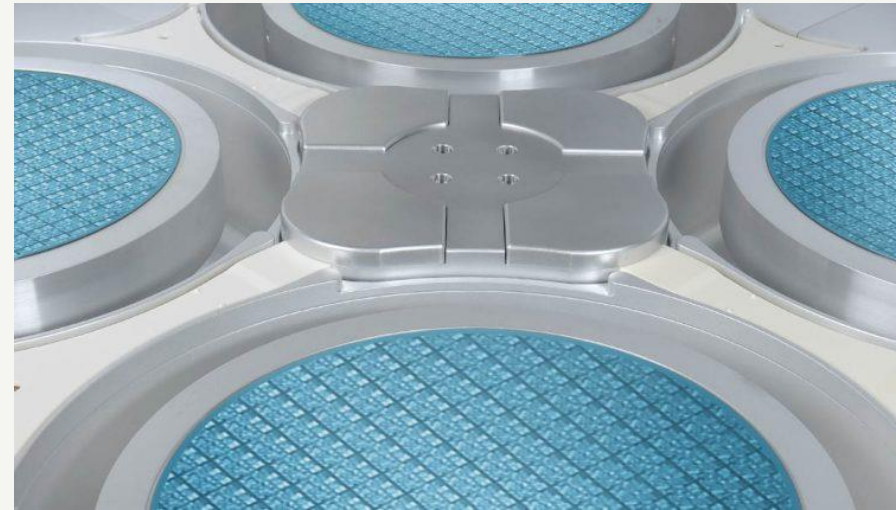
Drivers of ALD Equipment market Growth



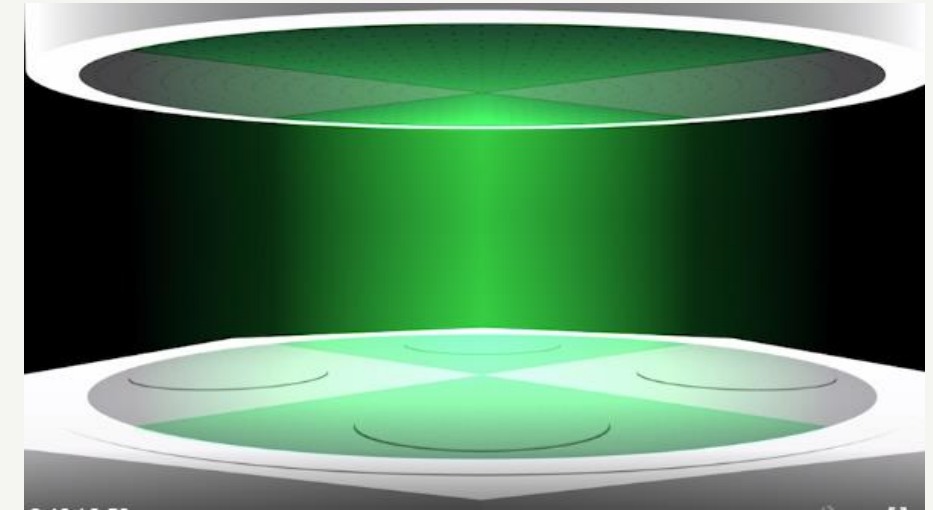
* Inclues Lithography, Etch, Deposition, Clean, etc.

Competition Schemes

- Bottom up – Competition on high-k layer
 - Differentiated mainly by chamber designs

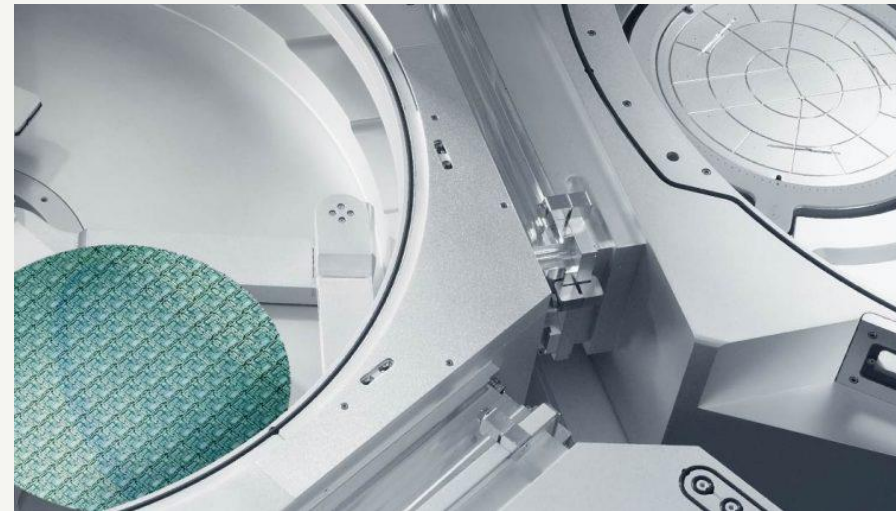


Lam Striker Family

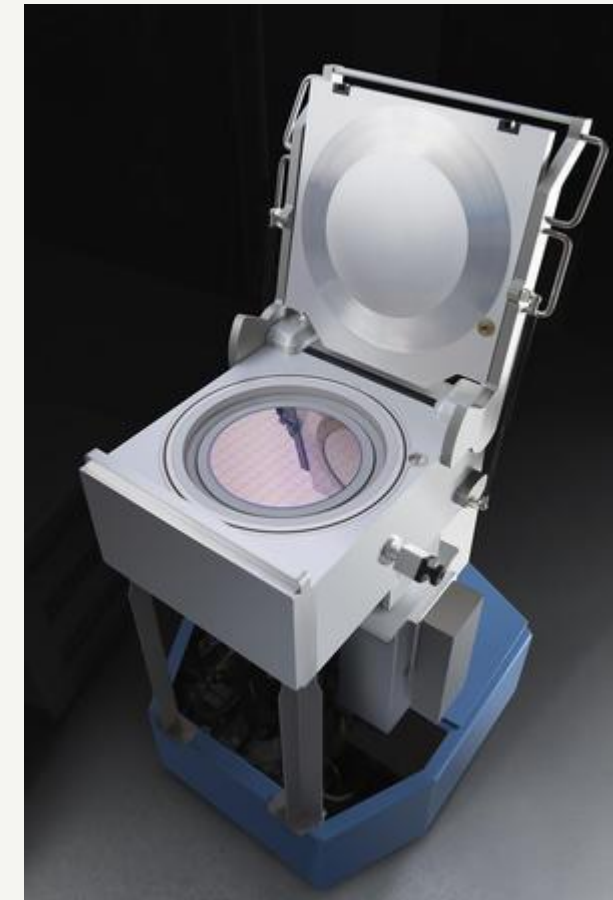


AMAT Olympia

-
- Top Down – Competition on barrier, seed layer
 - In-situ barrier, seed layer + Metal
 - Developed based on CVD Chamber + Pulsing



Lam Altus Family: ALD + CVD Capability



*AMAT Centura®
iSprint, ALD +
CVD Capability*

Market of ALD Equipment for Semiconductor App.

	Metal Gate Layer	Low-Temp Ox.	Capacitor Electrode	High-k Dielectric	Insulating Liner	Diffusion Barrier	Metal Seed Layer	In-situ Metal
ASM	EMERALD®	EMERALD®	EMERALD®	PULSAR®	PULSAR® SYNERGIS®	SYNERGIS®	SYNERGIS®	SYNERGIS®
Lam				Striker	Striker	ALTUS	ALTUS	ALTUS
AMAT				Olympia			Centura® iSprint	Centura® iSprint
Veeco					Firebird	Firebird	Firebird	
TEL*				NT333™		NT333™		
Picosun		Morpher (200mm)		Sprinter, Morpher (200mm)	Sprinter, Morpher (200mm)	Sprinter, Morpher (200mm)	Sprinter, Morpher (200mm)	Morpher (200mm)
etc.								

*TEL hs 5.4% shares of ASMI as of 2020

ALD Equipment Market Outlook

	Logic/Foundry + Memory
Market Trend	<ul style="list-style-type: none">▪ Logic/Foundry WFE Level off as major foundries put their most advanced node into HVM and the next generation is still on the way; ramp-up of US factories could boost overall Logic/Foundry growth▪ Memory WFE is expected to keep grow steadily▪ ALD Equipment market is expected to outperformance overall WFE due to higher involvement of advanced node and advanced memory structures
Competition	<ul style="list-style-type: none">▪ Major competition could be on memory side as tradition CVD players pursuing ALD capabilities.▪ High throughput is expected to be the key for winning the competition.▪ Integration solution will affect the purchase decisions